GIS for cartographic accuracy analysis of settlements in the province of Madrid (AGE Tomas Lopez 1804)

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Article Information

Keywords:
K1, GIS,
K2, Accuracy,
K2, Cartography
K4, Madrid
K5, Tomas Lopez

Abstract

Purpose:
In this paper we study all settlements shown on the map of the Province of Madrid, sheet number 1 of AGE (Atlas Geográfico de España of Tomas Lopez 1804) and their correspondence with the current ones. This map is divided in to zones: Madrid and Almonacid de Zorita.

Method:
The steps followed in the methodology are as follow: 1. Geo-reference of maps with latitude and longitude framework. Move the historical longitude origin to the origin longitude of modern cartography. 2 Digitize of all population settlements or cities (97 on Madrid and 42 on Almonacid de Zorita), 3 Identify historic settlements or cities corresponding with current ones. 4. If the maps have the same orientation and scale, replace the coordinate transformation of historical settlements with a new one, by a translation in latitude and longitude equal to the calculated mean value of all ancient map points corresponding to the new. 5. Calculation of absolute accuracy of the two maps. 6 draw in the GIS, the settlements accuracy.

Result:
It was found that all AGE settlements have good correspondence with current, ie only 27 settlements lost in Madrid and 2 in Almonacid. The average accuracy is 2.3 and 5.7 km to Madrid and Almonacid de Zorita respectively.

Discussion & Conclusion:
The final accuracy map obtained shows that there is less error in the middle of the map. This study highlights the great work done by Tomas Lopez in performing this mapping without fieldwork. This demonstrates the great value that has been the work of Tomas Lopez in the history of cartography.

1 Introduction

One of the first cartographic representations of Spain was made by the cartographer Tomas Lopez de Vargas y Machuca (1731-1802) [1].

1.1 Tomas Lopez´s method

López´s method - learned from his teacher D´Anville [2] - is what has been called “studio cartography” [3]. He specialized in a compilatory methodology that united his talents for synthesizing and solving, and which has been described as imprecise; he has been criticized for dispensing with astronomical and geometric observations and for not using field work to support the large volume of information he was able to gather [1]. He created his maps from a collection of previously existing ones, which were supplemented with information from his “interrogations”. These “interrogations” consisted of a questionnaire, which was directed at those responsible for each diocese or parish, and contained 15 questions about the most relevant data, varied in nature, pertaining to their communities [4]. Lopez also requested a small map of a three-league radius surrounding each territory, in which all of this information was to be included [1].

1.2 The Geographic Atlas of Spain of 1804 (Atlas Geografico de España AGE)

In 1788, Tomas Lopez began preliminary work on what then was the AGE. This was based on maps he had already made, and in a kind of dress rehearsal, published in 1790 the Private Atlas of the Kingdoms of Spain, Portugal and adjacent islands, commissioned by Carlos III [5]. The cartographic method used by Lopez, known as desk cartography, was based on a questionnaire sent to each village priest. In addition, each priest was required to provide a sketch of his village and 2 leagues surrounding it. Lopez composed a new sketch of the region based on the sketches provided by the village priests, other existing maps from the 16th, 17th and 18th centuries, and vast quantities of other documents (answers to questionnaires, local histories, geographical descriptions, and cartographic sketches) [1].

The AGE was the culmination of forty years of work experience of Tomas Lopez. He represented the map of mainland Spain more detailed done so far, distributed in 102 sheets with geographic information of the 36 territories that composed it. See figure 1.

1.3 Purpose

In this paper we study all settlements shown on the map of the Province of Madrid, sheets number 1 of AGE

(Atlas Geografico de España of Tomas Lopez 1804) and their correspondence with the current ones. This map is divided in to zones: Madrid and Almonacid de Zorita.

2 Method

According to [6], application of GIS in assessing of early maps can be divided into several steps:

First, the maps are georeferenced in the GIS with respect to their frame, using as map reference the ED50 system(European Datum 1950), and transferred to the origin of longitude of the current reference system of Spain (ED50), which is -16.6409096611º East, as the Greenwich Meridian was not adopted as origin of longitude until 1884 [7].

Taking into account the equivalent distance for 1º of longitude, we obtain the root mean square (RMS) errors of the georeferencing.

The different settlements are digitized in the GIS, these are represented on the map as points, and the geographic coordinates - latitude and longitude of their attribute table - are calculated. After this, the step is to identify locations of the points and features of an early map on a modern base map, i.e., to find strictly comparable points and features between the early map and the modern base map. This modern base map with the identified points and features is used as the reference map to evaluate the accuracy of the early map.

At this point, we have two sets of places: 1º TL (Tomas Lopez settlements) with corresponding with actual ones, these were called coincident points 2º TL (Tomas Lopez settlements) without corresponding with actual ones, these were called not coincident points.

These coordinates are compared with those of current population sites and of the group of coincident points, in order to avoid a possible systematic displacement error of the historical map. For this purpose, the coordinates of this historical map are shifted by the value of the mean error in both longitude and latitude. Total lineal error (ET_l) or accuracy is calculated in kilometers for each city:

ET_l (km)= $\sqrt{}$(x2+y2)

Finally, the ET_l of each population site is represented in the GIS with respect to the historical cartography coordinates; figures 1 and 2.

The software used in our work is ArcGIS 9 v.3 [8].

3 Results

We have digitizied all population settlements or cities of the two zones (Madrid and Almonacid de Zorita), finding 124 settlements on Madrid and 44 settlements on Almonacid de Zorita. Of the 168 sites across the sheet that was digitized, only 139 corresponded with their positions on current maps, been 97 of Madrid and 27 of Almonacid de Zorita). See tables 1 and 2 in the appendix section.

The table 3 shows the not coincident settlements of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Almonacid de Zorita; where only 2 settlements were not identified with current one

The table 4 shows the not coincident settlements of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Madrid; where 27 settlements were not identified with current one.

Original TL name	Longitude	Latitude
Hueva	-3.19982	40.46306
Valdeormena	-3.44167	40.31261

Tab. 3 Not coincident settlements of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Almonacid de Zorita.

Original TL name	Longitude	Latitude
Alameda	-3.74466	40.46001
Ambroz	-3.73094	40.42530
Barajas	-3.73180	40.48958
Bayona	-3.71911	40.16130
Bilches	-3.61411	40.31773
Canillas	-3.79373	40.47116
Canillejas Marq.	-3.76930	40.45187
Carabanchel de Abajo	-3.89058	40.40173
Carabanchel de Arriba	-3.89915	40.39401
Chamartin	-3.82801	40.47501
Chozas	-3.95881	40.76987
Foncarral	-3.84087	40.50416
Granja	-3.92572	40.47117
Guadamilla	-4.51063	40.18616
Moraleja la Mayor	-4.02232	40.25859
Ortaleza	-3.79673	40.48487
Pasadilla	-3.71988	40.62630
Polvoranca	-3.95898	40.34473
Rodajo	-3.92401	40.44587
Rojas Viveros	-3.71508	40.45358
S. Silvestre	-4.51736	40.10345
Sacedon de los Canales	-4.14176	40.37259
Torrejon de la Rivera o Torrejoncillo	-3.68766	40.43644
Vallecas	-3.76973	40.38673
Vicalvaro	-3.74723	40.40473
Villarta	-4.60020	40.16130
Villaverde	-3.85415	40.35887

Tab. 4 Not coincident settlements of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Madrid.

The total lineal error (ET_l) or accuracy was calculated for each coincident settlement. These results are shown in tables 1 and 2. Table 5 summarizes the statistic of these results.

Zone	STD	Max (km)	Min (km)	Average (km)
Madrid	1.39254	6.25672	0.09243	2.30593
Almonacid	2.62562	11.96202	1.49565	5.75465

Tab. 5 Statistics of accuracy of coincident settlements (Provincia de Madrid of AGE Tomas Lopez Cartography 1804).

Figures 1 and 2 show error maps for each zone. We can note the colour graduation according to the category of the error, which is distributed in 5 main intervals for Madrid: from 0 to 1 km, higher than 1 to 2 km, higher than 2 to 3 km, higher than 3 to 4 km, and higher than 4 km. And seven intervals for Almonacid de Zorita, been the fourth intervals included before and higher than 4 to 6 km, higher than 6 to 10 km, and higher than 10 km.

4 Discussion and conclusion

The methodology used in this study allows us to systematically determine the lineal errors or accuracy of the analyzed historical cartography. The errors obtained (2.3 and 5.7 km) are lower than those of other [9] by comparing historical and current cartographies. And also

for the specific work of Tomas Lopez in the AGE cartography, i.e. the 7.55 km for the Kindom of Jaen [5] or the 7.01 km for the Canary Islands [1]

Furthermore, this method allows us to quantify errors and to show them graphically in order to interpret the spatial distribution of errors in the historical cartography.

This study has shown that errors increase radially from central zone of the map toward the border of it. This leads to the conclusion that Tomas Lopez, in this map, began his cartographic representation works from contrasted points and he composed the map from this central point, accumulating errors in a concentric manner as he moved away from it, which is to be expected given that he did not have accurate geodetic references at his disposal. This does not exclude the possible influence of other factors such as settlements concentration, density of their population, communication network or the topography of the area.

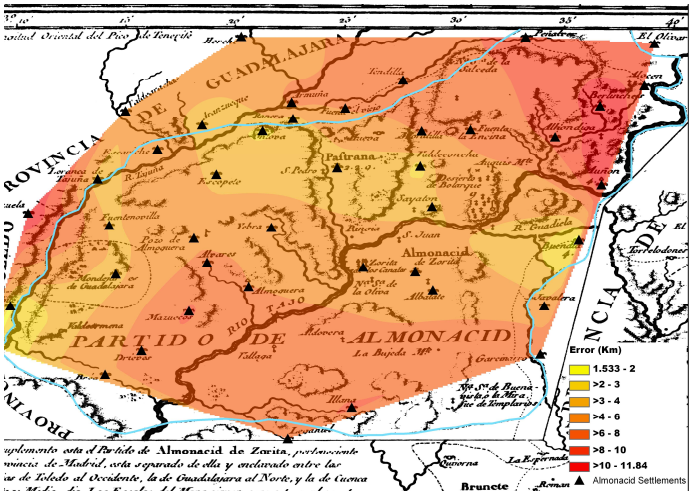

Fig. 3 Almonacid de Zorita accuracy map of Tomas Lopez cartography (AGE 1804).

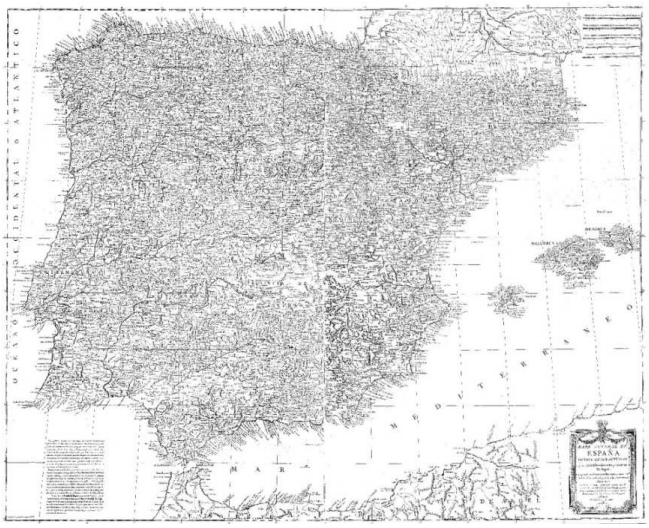

Fig. 1 AGE of Tomas Lopez (1804).

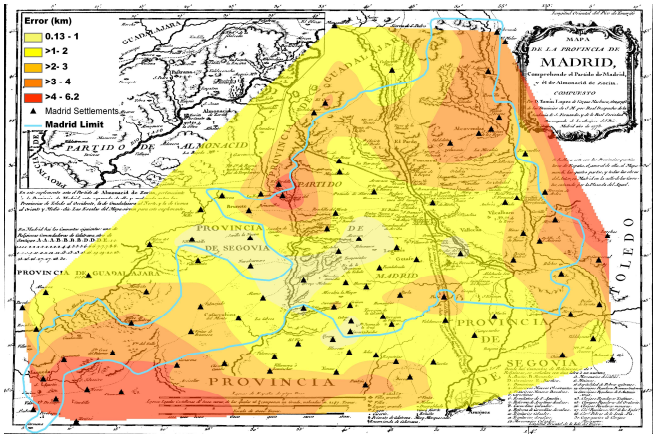

Fig. 2 Madrid accuracy map of Tomas Lopez cartography (AGE 1804).

Appendix

This appendix has the table 1 and 2, coincident settlements of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804.

Original TL name	Longitude	Latitude	ET_I (km)
Madrid	-4.16645	40.25644	1.00864649
Almonacid	-3.76531	40.56115	3.68156476
S. Agustin	-3.74774	40.67687	3.95610392
S. Fernando	-3.69451	40.44201	1.5701192
S. Martin	-3.73626	40.22173	0.91511622
S. Sebastian de los reyes	-3.74217	40.56887	4.04364572
Serranillos	-4.03445	40.24016	2.26915016
Sevilla la Nueva	-4.19019	40.36744	0.35984085
Torrejon de Ardoz	-3.64223	40.45316	2.99839362
Torrejon de la Calzada	-3.94347	40.22173	1.84270821
Torre de velasco	-3.92718	40.20716	1.41482826
Torrelodones	-4.07152	40.60015	2.01505203
Bacia madrid	-3.70094	40.32673	2.35276317
Valdelaguna	-3.55262	40.18102	1.48150542
Valdelatas	-3.81845	40.54358	3.86645405
Valdemoro	-3.82733	40.21445	1.63012377
Belilla de S. Antonio	-3.65209	40.36101	3.0382615
El Prado	-4.49092	40.29802	1.52984972
Villafranca del Caudillo	-4.13019	40.44673	5.76963918
Villamanta	-4.2873	40.32587	1.21103243
Villamantilla	-4.29851	40.36493	0.48753052
La Espernada	-4.17048	40.44973	1.86121997
El Pardillo	-4.13705	40.4673	4.62122438
Villaviciosa de Odon	-4.04727	40.38501	2.19582502
Alcabon	-4.59321	40.04988	5.77911463
Almorox	-4.5702	40.2663	1.79305341
Borox	-3.89332	40.10988	2.40699485
Camarena	-4.3263	40.1313	3.98068767
Casarruabios del Monte	-4.21188	40.21916	1.55992781
Chozas de Canales	-4.23802	40.13473	2.85272842
Escalona	-4.58777	40.19816	1.81205778
Esquivias	-3.91904	40.13816	2.05491008
Fuensalia	-4.42993	40.08245	4.8237215
Illescas	-4.00617	40.15616	1.22096317
Villanueva o Lominchar	-4.15359	40.12059	2.14623502
Maqueda	-4.57479	40.10645	4.01032103
Mentrida	-4.38335	40.26759	2.16481071
Noves	-4.49336	40.08716	5.16223026
Palomeque	-4.14502	40.14716	1.41971159
Pantoja	-3.97604	40.09573	3.78040972
Paredes	-4.61349	40.23887	2.11955567
Quismondo	-4.53634	40.14159	4.18307163

Santa Cruz de Retamar	-4.44605	40.15499	3.69647704
Seseña	-3.84961	40.1373	1.82864813
Torre de Estevan Ambron	-4.4112	40.2093	3.39290295
Torrijos	-4.5135	40.02802	5.95186401
Ugena	-4.03659	40.17973	0.70905154
Valde Santo Domingo	-4.55122	40.06873	6.25672473
Valmojado	-4.28259	40.24059	2.84957245
Ventas de Retamosa	-4.30016	40.19387	2.56376219
El Viso	-4.10088	40.17159	1.45317118
Letes (o Ietes)	-3.95632	40.15059	1.54683597
Yuncos	-4.03017	40.11888	1.47733596

Tab. 1 Coincident settlements and their accuracy of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Madrid.

Original TL name	Longitude	Latitude	ET_I (km)
Ambite	-3.48027	40.33163	1.89968311
Brea	-3.40811	40.27961	5.42198209
Oruses	-3.4978	40.30086	1.77000813
Pozuela	-3.46666	40.40211	11.9620158
Albalate	-3.15821	40.34375	4.93691022
Alvares	-3.3303	40.365	6.83709399
Alhondiga	-3.06507	40.46008	8.44507612
Almoguera	-3.29864	40.34636	6.02866218
Almonacid de Zorita	-3.1717	40.35773	4.57278026
Alocen	-2.9969	40.49905	9.28915654
Aranzueque	-3.33415	40.4694	3.57188459
Armuña	-3.26583	40.48656	6.52985614
Auñon	-3.02972	40.42409	11.1925072
Berlinches	-3.03076	40.48376	10.9906043
Drieves	-3.38033	40.29732	7.43709218
Escariche	-3.36808	40.45076	5.31614694
Escopete	-3.32322	40.43176	3.49201539
Fuente la Encina	-3.12949	40.46567	6.74568811
Fuente el Vicio	-3.22499	40.48227	6.12320973
Fuentenovilla	-3.40496	40.39279	3.81541176
Onlova (Ontova?)	-3.28802	40.46493	2.80268067
Horche	-3.30431	40.53671	4.91337202
Illana	-3.22011	40.25425	8.15177816
Lloranca de Tajuña	-3.41373	40.4284	3.07519049
Mazuecos	-3.34414	40.32771	8.23776605
Mondejar	-3.39993	40.35607	3.4653825
Moratilla	-3.16678	40.46474	6.39725301
El Olivar	-2.98926	40.5313	9.34033135
Pastrana	-3.23109	40.43681	3.06073926
Peñabres (o Peñalres)	-3.08744	40.53634	8.58854022
Pozo de Almoguera	-3.34037	40.38328	5.09770166
Ranera	-3.26483	40.47427	3.4018639
Sayaton	-3.15884	40.40712	3.87209041
Tendilla	-3.18095	40.50334	6.8979969
Valdearachas	-3.39251	40.48003	4.47681808
Valdeconcha	-3.16779	40.43789	2.59950626
Zorita de los Canales	-3.21133	40.36129	4.849248
Buendia	-3.04687	40.38177	1.49565492
Garcinarro	-3.07629	40.29471	7.9545158
Javalera	-3.07331	40.33163	4.30849033
Leganiel	-3.26876	40.23057	7.56335453
Yebra	-3.28127	40.39129	4.76732774

Tab. 2 Coincident settlements and their accuracy of the sheet number 1 (Provincia de Madrid) of AGE Tomas Lopez Cartography 1804, zone Almonacid de Zorita.

Acknowledgement

This study was funded by the HAR2009-12937 Project of the Spanish Ministry of Science and Innovation (Plan Nacional de I+D) titled “Análisis sistemático mediante tecnología GIS de la precisión planimétrica de los mapas del Atlas Geográfico de España de Tomás López de 1804”.

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